A REINFORCING COMPONENT

The present invention relates to a reinforcing component for a composite element for the building industry and to a composite element which incorporates the reinforcing component.

The present invention relates particularly to a reinforcing component for preventing longitudinal shear failure of the composite element.

The term "composite element" is understood herein to mean a beam, preferably but not necessarily formed from steel, and a solid or composite slab that are interconnected by shear connection to act together to resist action effects as a single structural member.

The term "shear connection" is understood herein to mean an interconnection between a beam and a solid or composite slab which enables the beam and the slab to act together as a single structural member.

In conventional composite elements, typically, the shear connection includes: (a) shear connectors, such as studs or reinforcing bar ligatures or structural bolts or channels, (b) slab concrete, and (c) transverse reinforcement.

The term "shear connector" is understood herein to mean a mechanical device such as a stud attached to a beam which forms part of the shear connection.

In particular, the present invention relates to composite elements of the type that include the following components:

(a) a horizontal beam (typically but not

necessarily steel) supported at each end;

(b) a composite slab positioned on and supported by the beam and including:

(i) sheeting, preferably profiled (typically but not necessarily steel) ;

(ii) concrete cast on the sheeting; and

(iii) reinforcement embedded in the concrete; and

(c) a plurality of shear connectors, typically in the form of headed studs, embedded in the concrete and extending through the sheeting at or adjacent to the ends or sides of the sheeting and connected to the beam thereby to connect the composite slab to the beam.

The present invention is concerned with reinforcing the type of composite element described above so that the composite element has sufficient shear capacity at the interface between the beam and the slab of the composite element to accommodate forces arising from compressive or tensile stresses caused by flexure of the beam to prevent premature shear failure of the shear connection (hereinafter referred to as "longitudinal shear failure") of the composite element.

The conventional reinforcement for preventing longitudinal shear failure in the type of composite element described above includes deformed reinforcing bars or welded wire fabric embedded in a horizontal position in the concrete of composite slabs. These reinforcing components are typically arranged to extend transversely to the longitudinal axis of the beam and therefore cross potential

longitudinal shear failure surfaces and by this mechanism are known to contribute to the longitudinal shear capacity of composite elements.

An object of the present invention is to provide a reinforcing component for preventing longitudinal shear failure of a composite element that is an alternative to and has advantages over the conventional reinforcement described in the preceding paragraph.

According to the present invention there is provided a shear reinforcing component for preventing longitudinal shear failure of a composite element for the building industry, which shear reinforcing component is an elongate member, such as a rod or a bar, that has been bent into a waveform configuration.

The waveform configuration may be any suitable form.

For example, the waveform configuration may be a square wave or a V-shaped, i.e. zig-zag, wave.

Preferably the square wave and the V-shaped wave include short straight sections and bends at the ends of the straight sections.

By way of further example, the waveform configuration may be generally sinusoidal.

The above-described shear reinforcing component can be located conveniently in the construction of a composite element to cross potential longitudinal shear failure surfaces and thereby contribute to the longitudinal shear capacity of the composite element.

In a situation in which the composite element

includes a horizontal beam and profiled sheeting that has pans separated by parallel ribs with the ribs transverse to the longitudinal axis of the beam, the shear reinforcing component can be positioned (prior to pouring concrete onto the sheeting to complete construction of the composite element) to rest on the ribs so as to extend along the line of the shear connectors connected to the beam.

The present invention is not confined to use with composite elements that include horizontal beams and profiled sheeting positioned so that the ribs are transverse to the longitudinal axis of the beams and can be used with composite elements in which the profiled sheeting is positioned with the ribs at any angle to the longitudinal axis of the beams.

Preferably the reinforcing member is a deformed bar.

Preferably the reinforcing member is a deformed steel bar having a yield stress of at least 400MPa.

More preferably the reinforcing member is a deformed steel bar having a yield stress of at least 500 MPa.

According to the present invention there is also provided a composite element which includes:

(a) a beam;

(b) a composite slab positioned on the beam, the composite slab including:

(i) sheeting;

(ii) concrete cast on the sheeting;

(c) a plurality of shear connectors that connect the composite slab to the beam; and

(d) a shear reinforcing component for preventing longitudinal shear failure embedded in the concrete slab, the reinforcing component being an elongate member, such as a rod or a bar, that has been bent into a waveform configuration and located to cross potential longitudinal shear failure surfaces and thereby contribute to the longitudinal shear capacity of the composite element.

Preferably the sheeting is profiled and has a plurality of pans separated by parallel ribs.

The sheeting may be positioned so that the ribs are parallel to or transverse to the longitudinal axis of the beam.

In a situation where the composite element includes a horizontal beam and profiled sheeting that has pans separated by parallel ribs with the ribs transverse to the longitudinal axis of the beam, preferably the shear reinforcing component is positioned to rest on the ribs and extend along the length of the beam.

Preferably the shear reinforcing component is positioned flat on the underlying components of the composite element and extends in a generally horizontal plane.

Preferably the shear reinforcing component is fully anchored on both sides where it passes through a potential longitudinal shear failure surface.

Preferably the reinforcement member is embedded in the slab below upper ends of the shear connectors.

Preferably the beam is a steel beam.

Preferably the beam is supported at each end.

In one embodiment, it is preferred that the composite element be an internal beam.

In another embodiment, it is preferred that the element be a perimeter or edge element.

It is preferred that the shear connectors be headed studs.

The shear connectors may be of any other suitable form such as structural bolts or channels welded or mechanically fastened to the steel beam.

According to the present invention there is also provided a method of manufacturing a reinforcing component for preventing longitudinal shear failure of a composite element for the building industry, which includes a step of bending an elongate member into a waveform configuration.

The present invention is described further by way of example with reference to the accompanying drawings in which:

Figure 1 is a perspective view which illustrates a conventional composite steel-framed building construction;

Figure 2 is a series of perspective views and transverse cross-sections that illustrate Type 1, 2, and 3 longitudinal shear failure surfaces; and

Figure 3 is a top plan view of a composite element, in simplified form, which illustrates four embodiments of a reinforcing component in accordance with the present invention.

The shear reinforcing component of the present invention is suitable particularly for providing so-called "transverse reinforcement" for preventing certain types of longitudinal shear failure when conventional welded-stud shear connectors are used with profiled steel sheets incorporating ribs separated by pans laid at any angle to supporting horizontal steel beams in the construction of steel-framed buildings.

Figure 1 illustrates a conventional construction of a steel-framed building.

With reference to Figure 1, the steel-framed building is an assemblage of composite elements that includes:

(a) an array of horizontally extending intersecting hot-rolled or fabricated steel beams 5 supported at each end;

(b) a composite slab including:

   (i) profiled steel sheeting 7 in contact with top flanges of the steel beams 5, the sheeting 7 including a plurality of parallel steel ribs 11 separated by pans 13; and

   (ii) concrete cast on the sheeting 7;

(c) a plurality of shear connectors in the form of headed studs 15 which may extend through

the sheeting 7 and are fastened to the top flanges of the beams 5; and

(d) conventional longitudinal shear reinforcing components in the form of a horizontally disposed mesh embedded in the concrete slab for preventing premature longitudinal shear failure of the composite element.

The composite element may be of any suitable dimensions and construction. Typically, the composite slab has an overall thickness of at least 120mm. In addition, the ribs of the sheeting 7 can have a dovetail profile, a trapezoidal profile or a profile of any other suitable shape.

The shear reinforcing component of the present invention is suitable particularly for providing longitudinal shear reinforcement for Type 1, 2 and 3 longitudinal shear failure surfaces as defined in Australian Standard AS 2327.1 for the above-described composite element.

These shear failure surfaces are illustrated by dotted lines in Figure 2.

It is noted that, whilst there is only one Type 1 shear failure surface shown in the top sketch of Figure 2, there may be a plurality of such shear failure surfaces extending from the ribs of the profiled steel sheeting shown in the sketch.

The shear reinforcing component of the present invention may be used as a replacement for or in addition to conventional longitudinal shear reinforcing components.

Figure 3 is a top plan view that illustrates in

diagrammatic form four embodiments of a shear reinforcing component in accordance with the present invention positioned to extend along a line of shear connectors 15 that are connected to an underlying beam (not shown).

Each of the embodiments includes a deformed steel bar 19a, 19b, 19c, 19d that has been bent into a zig-zag waveform configuration that has short straight sections. Each embodiment of the zig-zag reinforcing component is positioned flat on the underlying components of the composite slab and extends in a generally horizontal plane.

In the positions shown in Figure 3 the short straight sections of the zig-zag reinforcing components are transverse to a longitudinal axis of the beam.

In the case of the shear reinforcing components 19a, 19c, the wavelength of the zig-zag waveform is such that the reinforcing components fit between and do not clash with the shear connectors 15 and the reinforcing components sit on top of the ribs (not shown) of the underlying profiled steel sheeting of the composite slab.

However, depending on the shear connector spacing and the wavelength of the reinforcing components, the zig-zag waveform reinforcing components may clash with the shear connectors 15 when they are placed on site, noting that normal practice is to place the shear connectors 15 first. This is the case with the reinforcing components 19b, 19d shown in Figure 3.

Depending on the circumstances, there may be less clash with shear connectors 15 if different shaped waveforms, such as square or sinusoidal shaped waveform reinforcing components (not shown) are used.

In particular, it is noted that square waveform

shear reinforcing components may have alternating short and long outer straight sections so that transverse bars can effectively be positioned in pairs if desired, for example to concentrate bars between adjacent shear connectors 15 when the longitudinal shear forces are high, small diameter bars are used for improved anchoring efficiency, and/or to reduce the chance of the bars conflicting with the shear connectors 15.

The shear reinforcing component of the present invention can be manufactured at comparatively low cost using very rapid bar-bending equipment to form waveform bars of almost any conceivable shape.

The shear reinforcing component of the present invention can be made to any length subject to handling and transport restrictions.

The shear reinforcing component of the present invention can be anchored highly efficiently, and typically the distance between the outer edges of the waves and the line of shear connectors 15 that is required to anchor the component fully is about half that of conventional reinforcing components in the form of straight bars.

Preferably the shear reinforcing component of the present invention is fully anchored on both sides of a potential longitudinal shear failure surface where it crosses the surface so that it can develop its full tensile capacity when there is relative longitudinal movement between the adjacent concrete surfaces on opposite sides of a failure crack. By being able to develop its tensile capacity, the reinforcement restricts the width of a crack and creates a clamping force across the sliding surfaces. Aggregate interlock and frictional resistance develop which resist the longitudinal shear.

In AS 2327.1, the nominal longitudinal shear capacity per unit length of beam (V_L) of a Type 1, 2 or 3 shear longitudinal shear failure surface is assumed to equal:

$$V_L = 0.36\ \mu\sqrt{f'_c} + 0.9A_{sv}f_{sy}$$

The first term on the right-hand side of the above equation basically accounts for the resistance due to aggregate interlock.

The second term on the right-hand side of the equation can be thought of as a frictional clamping term with the design coefficient of friction between the sliding concrete surfaces equal to 0.9. f_{SY} is the yield stress bar.

Using this equation the reinforcement is assumed to be at 90 degrees to the sliding surfaces or crack.

If the reinforcement is at an acute angle θ to the sliding surfaces, then the equation for V_L becomes:

$$V_L = 0.36\ \mu\sqrt{f'_c} + 0.9A_{sv}\sin\theta f_{sy}$$

whereby the effectiveness of the reinforcement is reduced as a function of sin θ.

Different factors will determine if a zig-zag waveform reinforcing component of the present invention is more cost efficient than a square or other shape waveform reinforcing component of the present invention for a given situation.

Normally, it will be preferable to optimise the amount of material used, while limiting the chance of the reinforcement clashing with the shear connectors 15 on

site.

It is also preferable that the bars do not flop over when resting on the steel sheeting ribs (e.g. if square waveform bars are used that have the same pitch as the steel decking pans) and that the bars be sufficiently strong to be handled on site and to support light foot traffic without being permanently deformed out of plane.

Multiple rows of shear connectors 15 may be used and they may also be staggered.

Shear connector spacing may vary along a composite beam, but is normally stepped so as to keep the spacing constant within each step. Design engineers may choose shear connector spacings to suit standard bar patterns and sizes. Bars with different pitches may be cut to length on site. There is no need to overlap bars. It is common that shear connectors 15 will be more closely spaced towards the ends of beams. With prior knowledge of the shear connector spacings, the pitch along the waveform reinforcements can be varied as necessary during manufacture.

Many modifications may be made to the preferred embodiment of the reinforcing component and the composite element shown in the figures without departing from the spirit and scope of the present invention.